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[Title of the Invention] HEAD DRIVE APPARATUS AND METHOD FOR INKJET PRINTER

[Claims]

[Claim 1] A head drive apparatus, for an inkjet printer, in which a piezoelectric element, for pressurizing an ink chamber, provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a drive waveform generating circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive apparatus for an inkjet printer is characterized by comprising

a reference voltage generating circuit for applying an intermediate potential to a ground-side electrode of each piezoelectric element.

[Claim 2] A head drive apparatus for an inkjet printer according to claim 1, characterized in that said reference voltage generating circuit, for applying a charge voltage to each piezoelectric element with a different timing from the print timing of each piezoelectric element, includes: a voltage hold circuit for latching an arbitrary voltage of the drive signal from the drive waveform generating circuit based on a charge signal from piezoelectric element charging means for correcting a reduction in electric charge due to discharge of the piezoelectric element; and a current amplifying circuit for amplifying the output of the voltage hold circuit.

[Claim 3] A head drive apparatus for an inkjet printer according to claim 1 or 2, characterized in that said reference voltage generating circuit discharges the piezoelectric element when the potential of the drive signal is higher than the intermediate potential and charges the piezoelectric element

when the potential of the drive signal is lower than the intermediate potential.

[Claim 4] A head drive apparatus for an inkjet printer according to any one of claims 1 to 3, characterized in that based on the output of said voltage hold circuit, said reference voltage generating circuit outputs a reference voltage when the piezoelectric element charging means charges each piezoelectric element.

[Claim 5] A head drive apparatus for an inkjet printer according to claim 3 or 4, characterized in that said reference voltage generating circuit includes discharging means for discharging the piezoelectric element.

[Claim 6] An inkjet printer, characterized in having the head drive apparatus according to any one of claims 1 to 5.

[Claim 7] A head drive method, for an inkjet printer, in which a piezoelectric element, for pressurizing an ink chamber, provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a drive waveform generating circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive method for an inkjet printer is characterized in that

a reference voltage generating circuit applies an intermediate potential to a ground-side electrode of each piezoelectric element.

[Claim 8] A head drive method for an inkjet printer according to claim 7, characterized in that said reference voltage generating circuit applies a charge voltage to each piezoelectric element with a different timing from the print timing of each piezoelectric element, in which a voltage hold circuit latches an arbitrary voltage of the drive signal from the drive waveform generating circuit based on a charge signal from piezoelectric element

charging means for correcting a reduction in electric charge due to discharge of the piezoelectric element and a current amplifying circuit amplifies the output of the voltage hold circuit.

[Claim 9] A head drive method for an inkjet printer according to claim 7 or 8, characterized in that said reference voltage generating circuit discharges the piezoelectric element when the potential of the drive signal is higher than the intermediate potential and charges the piezoelectric element when the potential of the drive signal is lower than the intermediate potential.

[Claim 10] A head drive method for an inkjet printer according to any one of claims 7 to 9, characterized in that based on the output of said voltage hold circuit, said reference voltage generating circuit outputs a reference voltage when the piezoelectric element charging means charges each piezoelectric element.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a head drive technique, for an inkjet printer, configured such that the ground side of piezoelectric elements provided to correspond to nozzles for ejecting ink droplets is held at an intermediate potential.

[0002]

[Prior Art]

Conventionally, an inkjet color printer of the type in which inks of several colors are ejected from a printhead has prevailed as an output apparatus of a computer and has been widely used to print an image

processed by the computer or the like in multiple colors and tones.

[0003]

For example, an inkjet printer using a piezoelectric element as a drive element for ejecting ink is configured as follows. Plural piezoelectric elements provided to correspond to plural nozzles of a printhead are selectively driven. Thereby, ink droplets are ejected through the nozzles based on the dynamic pressure of the individual piezoelectric elements and adhered to print paper. Thereby, dots are formed on the print paper, thus performing printing.

[0004]

Here, each piezoelectric element, provided to correspond to each nozzle for ejecting an ink droplet, is driven by a drive signal supplied from a driver IC (head drive circuit) mounted in a printer body or the printhead, thus ejecting an ink droplet.

[0005]

In the meantime, in such a piezoelectric element, during non-drive (i.e. when printing is not performed), electric charge stored by charging is discharged due to insulation resistance and the voltage of the piezoelectric element is lowered, thereby affecting the ink ejection in some cases.

[0006]

Consequently, Japanese Patent No. 3097155 obtained by the present inventor discloses a head drive apparatus and method configured such that a charge voltage is applied to the piezoelectric element with a different timing from the drive timing, thus maintaining the charge voltage.

[0007]

[Problems that the Invention is to Solve]

However, in such head drive for the inkjet printer, the drive signal applied to each piezoelectric element is configured, for example, to be set to a high voltage during non-drive and have the voltage lowered during drive. In this case, power consumption becomes large and a voltage applied to the piezoelectric element becomes comparatively high. Therefore, a voltage drop due to the aforesaid discharging is also large, so that a power loss is large.

[0008]

Besides, when an increase in density of print dots is intended to be realized for an improvement in print quality, the gap between the electrodes of the piezoelectric elements adjacent to each other is narrowed. However, when the voltage between the electrodes of the driven piezoelectric element and the non-driven piezoelectric element is raised, in some cases, discharge occurs between the electrodes of these piezoelectric elements. Thus, insulating between the electrodes of the piezoelectric elements will be needed.

[0009]

On the contrary, there is also a head drive method such that the ground side of each piezoelectric element is held at the intermediate potential of the drive signal. According to such a head drive method, it is possible to prevent the discharge between the electrodes of the piezoelectric elements that occurs upon the aforesaid increase in density. However, in correspondence to variation in the drive signal, the voltage need be varied and charging and discharging need be switched, so that a bi-directional variable power supply will be needed.

[0010]

Furthermore, since the operating characteristics of the piezoelectric

element are changed in accordance with the temperature, power supply need be varied to correct the intermediate potential based on the temperature.

[0011]

Consequently, an object of the invention is to provide a head drive apparatus and method, for an inkjet printer, configured such as to be able to easily hold the intermediate potential of each piezoelectric element, with a simple configuration.

[0012]

[Means for Solving the Problems]

To solve the aforesaid problems, in the invention, a reference voltage from a reference voltage generating circuit is applied to a ground-side electrode of each piezoelectric element, thus holding the ground side of each piezoelectric element at an intermediate potential.

[0013]

That is, in the head drive apparatus for an inkjet printer according to claim 1, in which a piezoelectric element, for pressurizing an ink chamber, provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a drive waveform generating circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive apparatus for an inkjet printer is characterized by comprising a reference voltage generating circuit for applying an intermediate potential to a ground-side electrode of each piezoelectric element.

[0014]

Besides, in the head drive method for an inkjet printer according to

claim 7, in which a piezoelectric element, for pressurizing an ink chamber, provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a drive waveform generating circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive method for an inkjet printer is characterized in that a reference voltage generating circuit applies an intermediate potential to a ground-side electrode of each piezoelectric element.

[0015]

According to this configuration, the reference voltage generating circuit applies the intermediate potential directly to the ground-side electrode of the piezoelectric element. Thereby, the ground side of the piezoelectric element is held at the intermediate potential. Accordingly, the voltage applied between both electrodes of the piezoelectric element becomes comparatively low. Thereby, power consumption is reduced, and a voltage drop due to natural discharge of the piezoelectric element is small, so that a power loss is reduced.

[0016]

Besides, the voltage applied to the piezoelectric element becomes comparatively low, thereby reducing even the occurrence of discharge due to the voltage difference between the driven piezoelectric element and the non-driven piezoelectric element. Thus, the density of the head can be easily increased without performing insulating between the electrodes of the piezoelectric elements.

[0017]

Furthermore, the heat generation of the piezoelectric element is

reduced, so that the characteristic change of the piezoelectric element due to a temperature change is reduced. At the same time, even if the operating characteristics of the piezoelectric element are changed in accordance with the temperature, the reference voltage generating circuit always holds the ground side of the piezoelectric element at the intermediate potential. Thus, a temperature correction will no longer be needed.

[0018]

The head drive apparatus according to claim 2 is characterized in that the aforesaid reference voltage generating circuit, for applying a charge voltage to each piezoelectric element with a different timing from the print timing of each piezoelectric element, includes: a voltage hold circuit for latching an arbitrary voltage of the drive signal from the drive waveform generating circuit based on a charge signal from piezoelectric element charging means for correcting a reduction in electric charge due to discharge of the piezoelectric element; and a current amplifying circuit for amplifying the output of the voltage hold circuit.

[0019]

The head drive method according to claim 8 is characterized in that the aforesaid reference voltage generating circuit applies a charge voltage to each piezoelectric element with a different timing from the print timing of each piezoelectric element, in which a voltage hold circuit latches an arbitrary voltage of the drive signal from the drive waveform generating circuit based on a charge signal from piezoelectric element charging means for correcting a reduction in electric charge due to discharge of the piezoelectric element and a current amplifying circuit amplifies the output of the voltage hold circuit.

[0020]

According to this configuration, based on a charge signal from the piezoelectric element charging means for holding the charge voltage of the piezoelectric element, the voltage hold circuit of the reference voltage generating circuit latches the arbitrary voltage of the drive signal. Thereby, a desired reference voltage can be generated, and the current amplifying circuit amplifies a current based on the reference voltage. Thereby, the ground-side electrode of the piezoelectric element is charged using a comparatively large current. Thus, the ground-side electrode of the piezoelectric element can be held at the intermediate potential. Accordingly, the charge voltage need not be varied as has been conventional, so that a variable power supply is not needed.

[0021]

Besides, based on the drive signal from the drive waveform generating circuit, a current is amplified to thereby generate the reference voltage. Therefore, by utilizing a constant voltage power supply for use in amplifying the current of the drive signal, another power supply line need not be dragged around, so that the conventional circuit can be utilized as it is.

[0022]

The head drive apparatus according to claim 3 is characterized in that the aforesaid reference voltage generating circuit discharges the piezoelectric element when the potential of the drive signal is higher than the intermediate potential and charges the piezoelectric element when the potential of the drive signal is lower than the intermediate potential.

[0023]

The head drive method according to claim 9 is characterized in that the aforesaid reference voltage generating circuit discharges the piezoelectric element when the potential of the drive signal is higher than the intermediate potential and charges the piezoelectric element when the potential of the drive signal is lower than the intermediate potential.

[0024]

According to this configuration, based on the drive signal, the reference voltage generating circuit charges and discharges the piezoelectric element. Thereby, the ground-side electrode of the piezoelectric element is held at the intermediate potential, so that a bi-directional variable power supply will not be needed.

[0025]

The head drive apparatus according to claim 4 is characterized in that based on the output of the aforesaid voltage hold circuit, the aforesaid reference voltage generating circuit outputs a reference voltage when the piezoelectric element charging means charges each piezoelectric element.

[0026]

The head drive method according to claim 10 is characterized in that based on the output of the aforesaid voltage hold circuit, the aforesaid reference voltage generating circuit outputs a reference voltage when the piezoelectric element charging means charges each piezoelectric element.

[0027]

According to this configuration, when the piezoelectric element charging means charges the piezoelectric element before printing, the reference voltage generating circuit outputs the reference voltage to the

ground-side electrode of the piezoelectric element. Thereby, both electrodes of the piezoelectric element are charged almost without causing the voltage difference therebetween, so that the piezoelectric element is prevented from malfunctioning. Accordingly, the piezoelectric element before printing can be rapidly charged for a short time period.

[0028]

The head drive apparatus according to claim 5 is characterized in that the aforesaid reference voltage generating circuit includes discharging means for discharging the piezoelectric element.

[0029]

According to this configuration, when the potential of the piezoelectric element is higher than the intermediate potential, the piezoelectric element is discharged via this discharging means. Thereby, the ground side of the piezoelectric element can be held at the intermediate potential.

[0030]

[Mode for Carrying out the Invention]

A head drive apparatus according to embodiments of the invention will be described with reference to the drawings. Additionally, since the embodiments to be described below are preferred embodiments of the invention, various technically preferable limitations are put thereon. However, the scope of the invention is not limited to these embodiments unless the following description specifically states any limitation on the invention.

[0031]

Fig. 1 shows the configuration of an embodiment of the head drive apparatus according to the invention. In Fig. 1, the head drive apparatus 10

comprises: a piezoelectric element 11 provided to correspond to each of plural nozzles of an inkjet printer; a drive waveform generating circuit 12 for supplying a drive signal to one-side electrode 11a of each piezoelectric element 11; a current amplifying circuit 13 and a switch circuit 14 that are provided between this drive waveform generating circuit 12 and each piezoelectric element 11; and a reference voltage generating circuit 20 for applying a predetermined voltage to the other, ground-side electrode 11b of the piezoelectric element 11. Out of such components configuring the head drive apparatus 10, in this embodiment, the drive waveform generating circuit 12, reference voltage generating circuit 20, and current amplifying circuit 13 are provided in a printer body section 100, while the piezoelectric element 11 and switch circuit 14 are provided in a head section 200. Here, Fig. 1 shows only one piezoelectric element 11. However, actually, a head of the inkjet printer is provided with plural nozzles and one piezoelectric element is provided to correspond to each nozzle. And, as shown in Fig. 1, upon receipt of a control signal CS, the switch circuit 14 is turned on with the drive timing of the corresponding piezoelectric element 11 of the plural piezoelectric elements, thus outputting the drive signal COM described later to the piezoelectric element 11. Additionally, the drive signal COM from the drive waveform generating circuit 12 is sequentially outputted to each piezoelectric element 11, actually via a shift register or the like.

[0032]

The piezoelectric element 11, which is a piezo-element for example, is configured to be displaced by a voltage applied between both electrodes 11a and 11b. And, the piezoelectric element 11 is always charged in the vicinity of

an intermediate potential. When discharged based on the drive signal COM from the drive waveform generating circuit 12, the piezoelectric element 11 is configured to pressurize ink in the corresponding nozzle to thereby eject an ink droplet through this nozzle.

[0033]

The drive waveform generating circuit 12 generates the drive signal COM for the head of the inkjet printer and in this embodiment, as aforesaid, is disposed in the printer body section.

[0034]

The current amplifying circuit 13 comprises two transistors: a first transistor 15 and a second transistor 16. The first transistor 15 has a collector connected to a not-shown constant voltage power supply, a base connected to the output of the drive waveform generating circuit 12, and an emitter connected to the input side of the switch circuit 14. Thereby, electrical conduction is established based on the drive signal from the drive waveform generating circuit 12, thus supplying a VH voltage to the piezoelectric element 11 via the switch circuit 14.

[0035]

Besides, the second transistor 16 has an emitter connected to the input side of the switch circuit 15, a base connected to the output of the drive waveform generating circuit 12, and a collector connected to ground. Thereby, electrical conduction is established based on the drive signal from the drive waveform generating circuit 12, thus discharging the piezoelectric element 11 via the switch circuit 14.

[0036]

Upon receipt of the control signal CS, the switch circuit 14 is turned on with the drive timing of the corresponding piezoelectric element 11, thus outputting the drive signal COM to the piezoelectric element 11.

[0037]

The reference voltage generating circuit 20 is configured to apply a predetermined voltage to the other electrode 11b of the piezoelectric element 11. Here, this predetermined voltage can be set to a voltage, for example, substantially equal to the intermediate potential based on the drive signal COM, of the piezoelectric element 11. Such a configuration example will be described with reference to Fig. 2.

[0038]

In the example shown in Fig. 2, the reference voltage generating circuit 20 is configured as an intermediate voltage generating circuit 20A. The output side of this intermediate voltage generating circuit 20A is connected to the other electrode 11b of the piezoelectric element 11. Besides, the input side of the intermediate voltage generating circuit 20A is connected to the drive waveform COM output side of the drive waveform generating circuit 12, to which input side is inputted the drive signal COM from the drive waveform generating circuit 12.

[0039]

Here, as shown in Fig. 3, the intermediate voltage generating circuit 20A specifically comprises, for example, a voltage hold circuit 21 and a current amplifying circuit 22.

[0040]

The voltage hold circuit 21 is configured to be charged based on the

drive signal from the drive waveform generating circuit 12 with the timing of charging the piezoelectric element 11 based on a charge signal NCHG for the piezoelectric element 11. The current amplifying circuit 22 comprises two transistors: a third transistor 23 and a fourth transistor 24.

[0041]

The third transistor 23 has a collector connected to the not-shown constant voltage power supply, a base connected to the output of the voltage hold circuit 21, and an emitter connected to the ground-side electrode (common terminal) of the piezoelectric element 11 via a forward diode 23a. Thereby, electrical conduction is established based on a signal from the voltage hold circuit 21, thus applying the VH voltage to the ground-side electrode 11b of the piezoelectric element 11.

[0042]

Besides, the fourth transistor 24 has an emitter connected to the ground-side electrode (common terminal) of the piezoelectric element 11 via a reverse diode 24a, a base connected to the output of the voltage hold circuit 21, and an emitter connected to ground. Thereby, electrical conduction is established based on a signal from the voltage hold circuit 21, thus discharging the ground-side electrode 11b of the piezoelectric element 11.

[0043]

Fig. 4 shows a specific configuration example of the aforesaid voltage hold circuit 21. In Fig. 4, the voltage hold circuit 21 comprises an analog switch 25, a charging capacitor 26, a hold reset circuit 29, and an analog amplifier 27.

[0044]

The analog switch 25, which is of well-known configuration,

comprises two oppositely connected FETs 25a and 25b and an inverter 25c. The aforesaid charge signal NCHG is inputted via the inverter 25c to the gate electrode of one FET 25a and directly to the gate electrode of the other FET 25b. At the same time, the drive signal COM from the drive waveform generating circuit 12 is inputted to the source electrodes of both FETs 25a and 25b.

[0045]

The charging capacitor 26 has one electrode connected to the drain electrodes of both FETs 25a and 25b and the other electrode connected to ground. Additionally, to accommodate self-discharge due to the input impedance of the analog amplifier 27, the capacity of the charging capacitor 26 is properly selected to provide a time constant such as not to affect the cycles of the charge signal. Additionally, the hold reset circuit 29 comprises a fifth transistor 30, and a hold reset signal is inputted to the base of the fifth transistor 30. Thereby, electric conduction is established between the collector and emitter of the fifth transistor 30, thus discharging the remaining voltage of the charging capacitor 26.

[0046]

The analog amplifier 27 has one input terminal connected to the one electrode of the charging capacitor 26 and two output terminals connected to the respective bases of two transistors 23 and 24 of the aforesaid current amplifying circuit 22. Furthermore, the output of the aforesaid current amplifying circuit 22 is fed back to the other input terminal of the analog amplifier 27.

[0047]

Here, when the piezoelectric element is charged, the current from the constant voltage power supply of the current amplifying circuit 22 is properly selected so that a current flowing through the piezoelectric element 11 via the first transistor 15 reaches the same peak current as a current discharged from the piezoelectric element 11 via the fourth transistor 24. Besides, when the piezoelectric element is discharged, the current from the constant voltage power supply of the current amplifying circuit 22 is properly selected so that a current discharged from the piezoelectric element 11 via the second transistor 16 reaches the same peak current as a current flowing through the piezoelectric element 11 via the third transistor 23.

[0048]

The head drive apparatus 10 according to this embodiment is configured as aforesaid and operates as follows based on the head drive method according to the invention. The head drive method according to an embodiment of the invention will hereinafter be described in detail with reference to the timing diagram of Fig. 5 and the flow chart of Fig. 6.

[0049]

First, at the time of print start (START) of the inkjet printer, as shown in Fig. 5A, the charge signal NCHG is inverted to a Low level for a time period of 100 μs for example (step S1 in Fig. 6). Thereby, the potential of the drive signal COM from the drive waveform generating circuit 12 is raised to the intermediate potential (step S2 in Fig. 6). Thereby, the drive signal COM causes a current to flow from the first transistor 15 of the current amplifying circuit 13 via the switch circuit 14 to the one-side electrode 11a of the piezoelectric element 11, thus charging the one-side electrode 11a of the

piezoelectric element 11. Thereby, the potential of the one-sdie electrode 11a of the piezoelectric element 11 is raised to the intermediate potential, as shown in solid line in Fig. 5B.

[0050]

AT this time, with the inversion of the charge signal NCHG, the charging capacitor 26 of the voltage hold circuit 21 is charged via the analog switch 25. Thereby, the arbitrary voltage of the drive signal COM is latched and outputted from the analog amplifier 27. Thereby, the third transistor 23 of the current amplifying circuit 22 conducts, so that a current flows from the aforesaid not-shown constant voltage power supply via the diode 23a to the ground-side electrode 11b of the piezoelectric element 11. Thereby, as shown in dotted line in Fig. 5B, the potential of the ground-side electrode 11b of the piezoelectric element 11 is also gradually raised to reach the intermediate potential (step S3 in Fig. 6).

[0051]

Here, as shown in Fig. 5B, the potential of the ground-side electrode 11b of the piezoelectric element 11 reaches the intermediate potential along substantially the same gradient as the potential of the drive signal COM. Therefore, the potential difference between both electrodes 11a and 11b of the piezoelectric element 11 is held at substantially zero. Accordingly, the time period to reach the intermediate potential of both electrodes 11a and 11b of the piezoelectric element 11 at the time of START need not be 100 μs for example as has been conventional. Even if the aforesaid time period is set to a shorter time period, for example, 20 μs or 10 μs, the piezoelectric element 11 will not malfunction ejecting an ink droplet.

[0052]

Then, during printing, the drive signal COM is outputted to the voltage hold circuit 21 (step S4 in Fig. 6). Based on variation in this drive signal COM, when the potential of the drive signal COM is higher than the intermediate potential, the one-side electrode 11a of the piezoelectric element 11 is charged via the first transistor 15 of the current amplifying current 13. Besides, when the potential of the drive signal COM is lower than the intermediate potential, the one-side electrode 11a of the piezoelectric element 11 is discharged via the second transistor 16 of the current amplifying circuit 13 (No in step S5 in Fig. 6). Thereby, the piezoelectric element 11 operates based on the drive signal COM, thus ejecting an ink droplet.

[0053]

Here, to prevent the voltage of the charging capacitor 26 from dropping halfway due to self-discharge and lowering below the intermediate potential as shown by reference character X in Fig. 5B, the charge signal NCHG is outputted (step S6 in Fig. 6). That is, as shown by reference character Y in Fig. 5C, the charge signal NCHG generates L level pulses at regular cycles of the drive signal COM, i.e., with each timing such that there appears no variation in the drive signal COM. Thereby, based on the drive signal COM from the drive waveform generating circuit 12, the one-side electrode 11a of the piezoelectric element 11 is charged via the first transistor 15 of the current amplifying circuit 13. Thus, each time, the potential of the one-side electrode 11a of the piezoelectric element 11 is raised to the intermediate potential.

[0054]

At this time, simultaneously, the L level pulses of this charge signal NCHG causes a predetermined voltage to be applied to the ground-side electrode 11b of the piezoelectric element 11 via the third transistor 23 of the current amplifying circuit 22 of the reference voltage generating circuit 20. Thereby, the ground-side electrode 11b of the piezoelectric element 11 is charged and similarly held at the intermediate potential.

[0055]

Thereby, even if the charging capacitor 26 is self-discharged, based on each L level pulse Y of the charge signal NCHG, both electrodes 11a and 11b of the piezoelectric element 11 are each charged and can thereby be held at the intermediate potential. The aforesaid operations of steps S4 to S6 are repeated until print end (No in step S7 in Fig. 6).

[0056]

Furthermore, at the time of print end (Yes in step S7 in Fig. 6), a predetermined END operation is performed (step S8 in Fig. 6). That is, as shown in Fig. 5A, the drive signal COM from the drive waveform generating circuit 12 is discharged from the one-side electrode 11a of the piezoelectric element 11 via the second transistor of the current amplifying circuit 13 and thereby lowered to the Low level. At this time, simultaneously, the fourth transistor 24 of the current amplifying circuit 22 of the reference voltage generating circuit 20 conducts. Then, the ground-side electrode 11b of the piezoelectric element 11 is discharged via the fourth transistor 24, so that its potential reaches the Low level. Here, as shown in Fig. 5B, the potential of the ground-side electrode 11b of the piezoelectric element 11 reaches the Low level along substantially the same gradient as that of the drive signal COM.

Therefore, the potential difference between both electrodes of the piezoelectric element 11 is held at substantially zero.

[0057]

Besides, once the drive signal COM reaches the Low level, a hold reset signal is issued to the aforesaid hold reset circuit 29 (step S9 in Fig. 6). That is, the hold reset signal is inputted to the base of the fifth transistor 30 of the hold reset circuit 29. Thereby, electric conduction is established between the collector and emitter of the fifth transistor 30, thus discharging the remaining voltage of the charging capacitor 26. Thereby, the sequence of the head drive method according to this embodiment ends.

[0058]

Thus, the output of the reference voltage generating circuit 20, i.e., the potential of the ground-side electrode 11b of the piezoelectric element 11 is held at the intermediate potential, all the time from print start to print end, following the drive signal COM from the drive waveform generating circuit 12 except a pulse waveform formed at the time of print timing. Therefore, the potential difference between both electrodes 11a and 11b of the piezoelectric element 11 is held at substantially zero.

[0059]

Accordingly, even if the rise time to reach the intermediate potential of the piezoelectric element 11 at the time of print start is made shorter than conventional 100 μs, malfunction of the piezoelectric element 11 will not occur, so that the print time from print start to print end can be shortened.

[0060]

Besides, the reference voltage generating circuit 20 charges and

discharges the ground-side electrode 11b of the piezoelectric element 11. Therefore, the need for a bi-directional variable power supply is eliminated as compared with the case of holding the ground side of the piezoelectric element 11 at the intermediate potential using the conventional power supply circuit.

[0061]

Furthermore, the maximum value of the peak current, obtained when the one-side electrode of the piezoelectric element 11 is charged and discharged based on the drive signal COM, suffices for the current needed when the piezoelectric element 11 is charged and discharged. Therefore, another power supply line need not be dragged around. Accordingly, when the head drive apparatus 10 is mounted in the print head, a small number of power supply lines suffice therefor. To connect the head drive apparatus 10 and the printer body, the same FFC (Flexible Flat Cable) as a conventional one can be used, and the occurrence of an L-shaped bend can be reduced.

[0062]

Besides, the voltage hold circuit 21 of the reference voltage generating circuit 20 operates based on the drive signal COM from the drive waveform generating circuit 12, so that adjustment is easy.

[0063]

Furthermore, the ground-side electrode 11b of the piezoelectric element 11 is always held at the intermediate potential. Thus, the drive voltage applied between both electrodes 11a and 11b of the piezoelectric element 11 is lowered. Accordingly, power consumption in the piezoelectric element 11 is reduced, and the voltage drop due to self-discharge of the piezoelectric element 11 is small, so that a power loss is reduced. Besides, the potential

difference between the driven piezoelectric element and the non-driven piezoelectric element becomes small. Therefore, when such piezoelectric elements are adjacent to each other, the occurrence of discharge between the piezoelectric elements is reduced. Thus, an increase in density of the head can be easily realized without performing insulating between the piezoelectric elements.

[0064]

Furthermore, the heat generation of the piezoelectric element is reduced, so that the characteristic change of the piezoelectric element due to a temperature change is reduced. At the same time, even if the operating characteristics of the piezoelectric element are changed in accordance with the temperature, the reference voltage generating circuit always holds the ground side of the piezoelectric element at the intermediate potential. Thus, a temperature correction such as required when a reference voltage is supplied from a variable power supply will no longer be needed.

[0065]

In the aforesaid embodiment, the piezoelectric element 11 uses a piezo-element for example but is not limited thereto. Alternatively, another piezoelectric element such for example as an electrostriction element or a magneto-striction element may be used.

[0066]

[Advantage of the Invention]

As described above, according to the invention, the reference voltage generating circuit supplies the intermediate potential directly to the ground-side electrode of the piezoelectric element. Thereby, the ground side of the

piezoelectric element is held at the intermediate potential. Accordingly, the voltage applied between both electrodes of the piezoelectric element becomes comparatively low. Thus, power consumption is reduced, and the voltage drop due to natural discharge of the piezoelectric element is small, so that a power loss is reduced.

[Brief Description of the Drawings]

[Fig. 1]

A block diagram showing the configuration of an embodiment of a head drive apparatus according to the invention;

[Fig. 2]

A block diagram showing a configuration example in which a reference voltage generating circuit in the head drive apparatus of Fig. 1 is replaced with an intermediate voltage generating circuit;

[Fig. 3]

A block diagram showing a configuration example of the intermediate voltage generating circuit of Fig. 2 provided with a voltage hold circuit;

[Fig. 4]

A block diagram showing a specific configuration example of the voltage hold circuit of Fig. 3;

[Fig. 5]

A timing diagram showing variations in (A) a drive signal, (B) the voltages of both electrodes of a piezoelectric element, and (C) a charge signal in the head drive apparatus of Fig. 1; and

[Fig. 6]

A flow chart explaining the operation of a drive method of the head

drive apparatus of Fig. 1.

[Description of the Reference Numerals and Signs]

10: Head drive apparatus

11: Piezoelectric element

11a: One-side electrode

11b: Ground-side electrode

12: Drive waveform generating circuit

13: Current amplifying circuit

14: Switch circuit

15: First transistor

16: Second transistor

20: Reference voltage generating circuit

21: Voltage hold circuit

22: Current amplifying circuit

23: Third transistor

24: Fourth transistor

25: Analog switch

26: Charging capacitor

27: Analog amplifier

[Designation of Document] ABSTRACT

[Abstract]

[Problem] An object of the invention is to provide a head drive apparatus and method, for an inkjet printer, configured such as to be able to easily hold the intermediate potential of each piezoelectric element, with a simple configuration.

[Means for Resolution] A head drive apparatus 10, for an inkjet printer, in which A piezoelectric element 11, for pressurizing ink, provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal COM from a drive waveform generating circuit 12, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive apparatus 10 is configured to comprise a reference voltage generating circuit 20 for applying an intermediate potential to a ground-side electrode 11b of each piezoelectric element.

[Selected Drawing] Fig. 1

Fig. 1

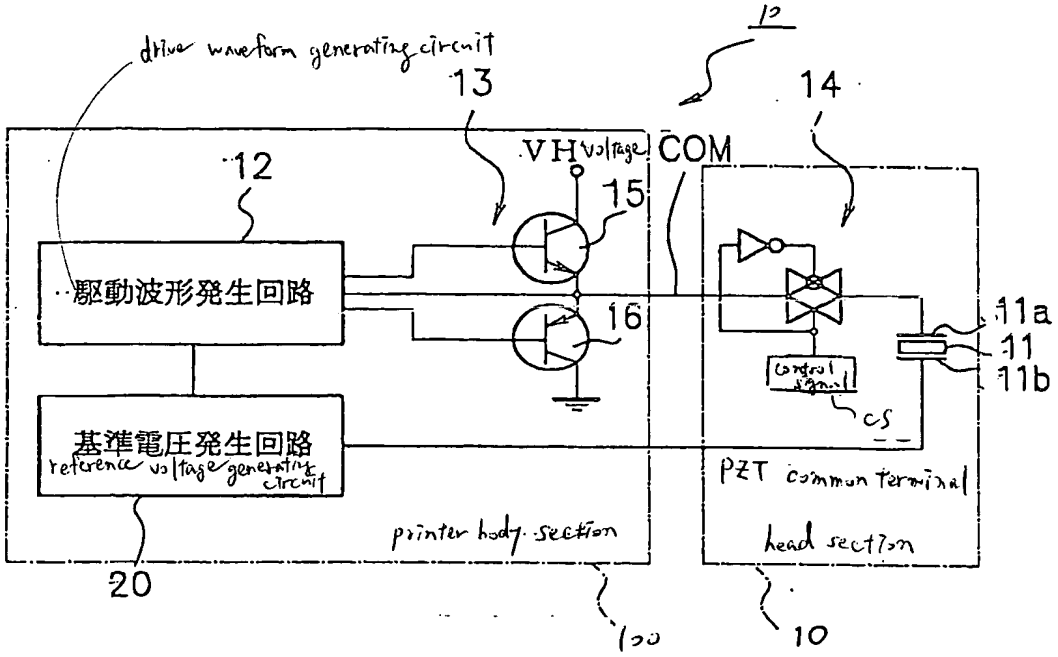


Fig. 2

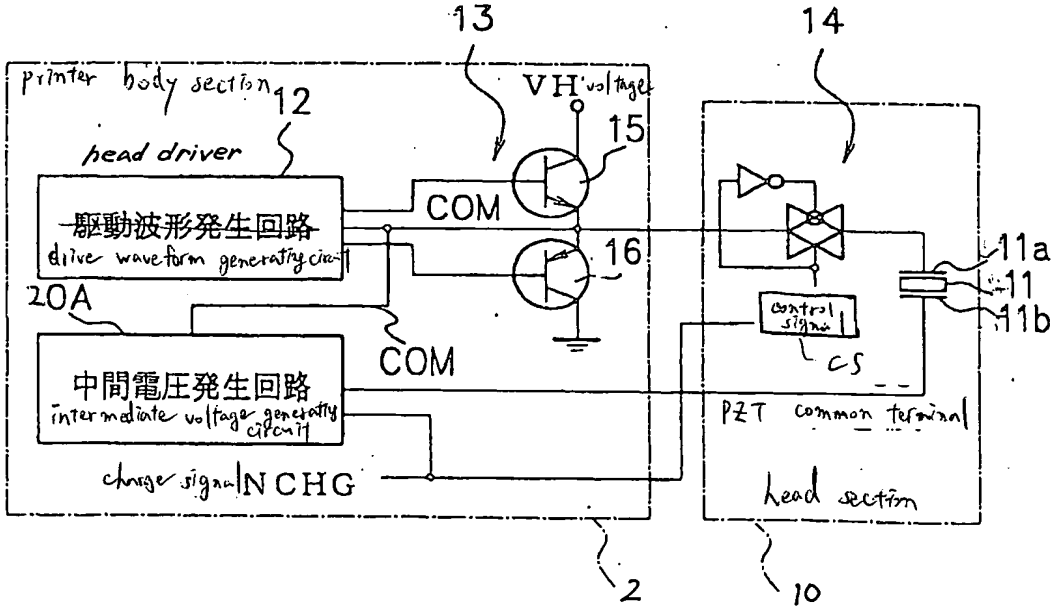


Fig. 3

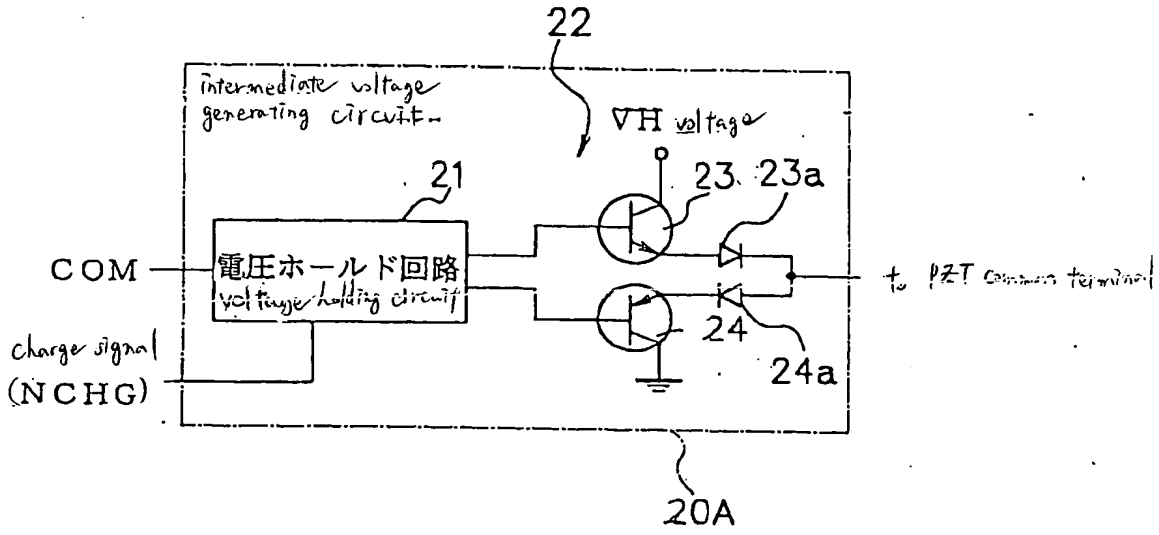
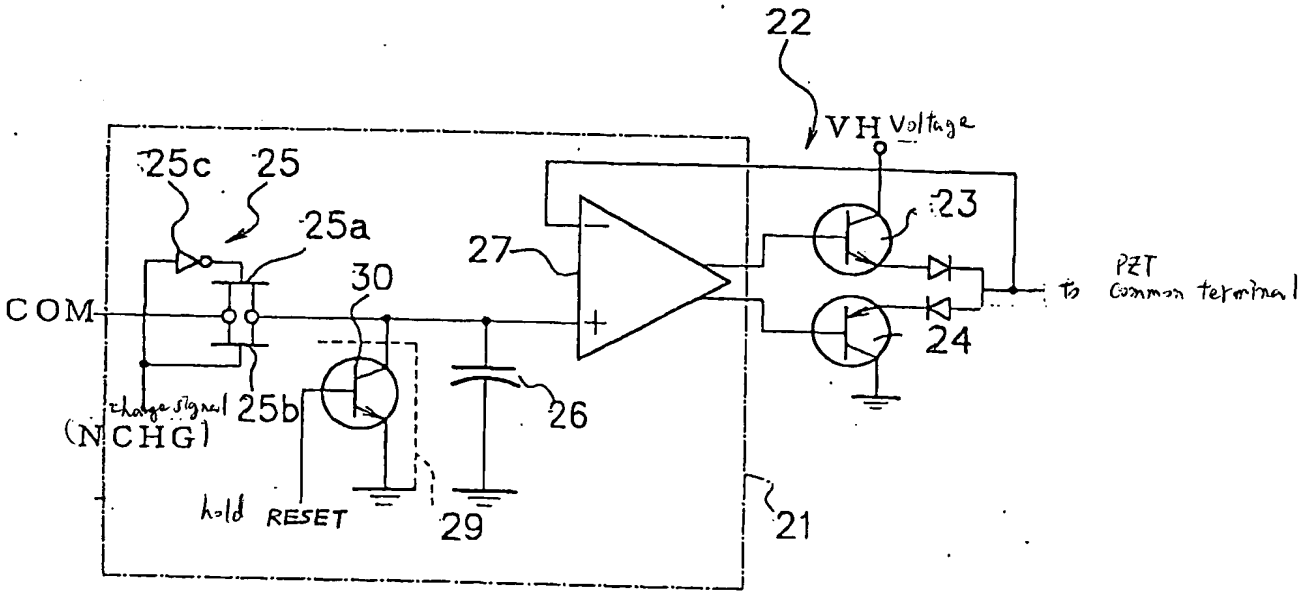


Fig. 4



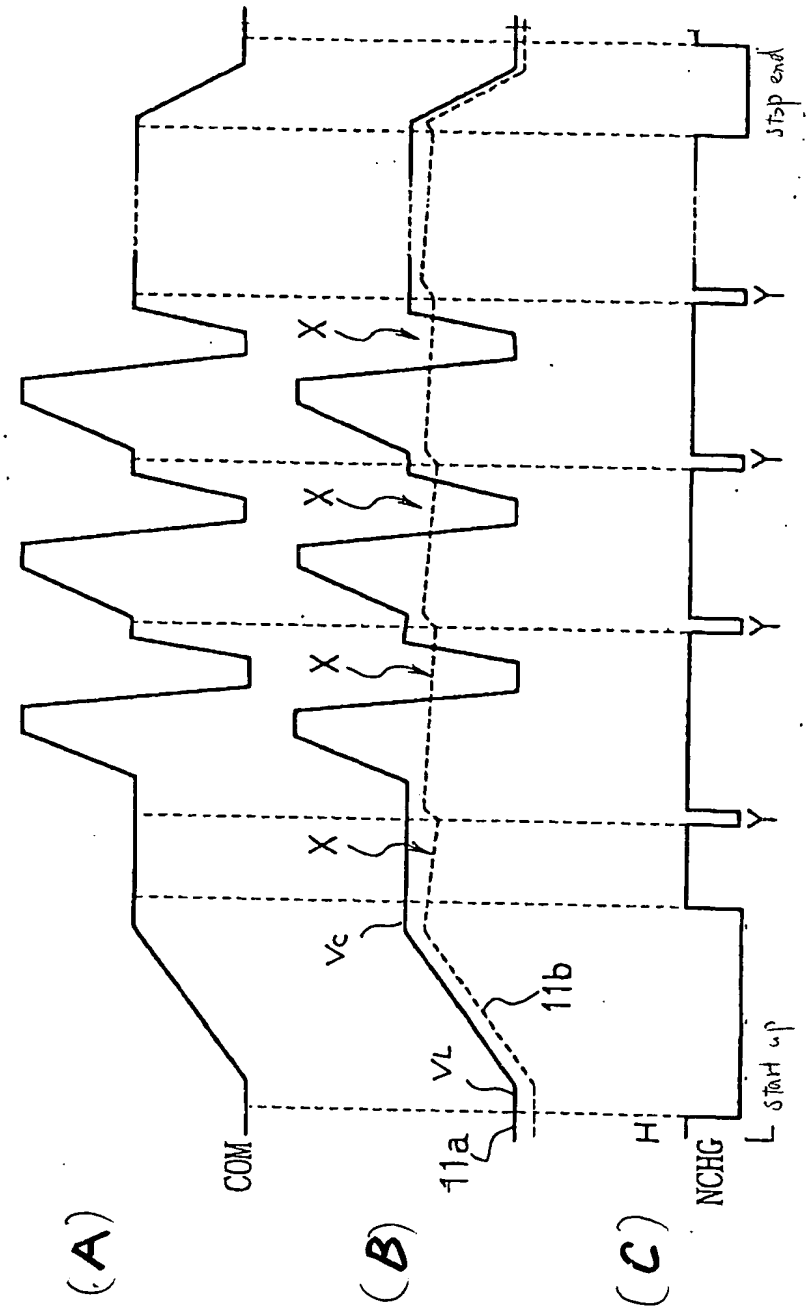
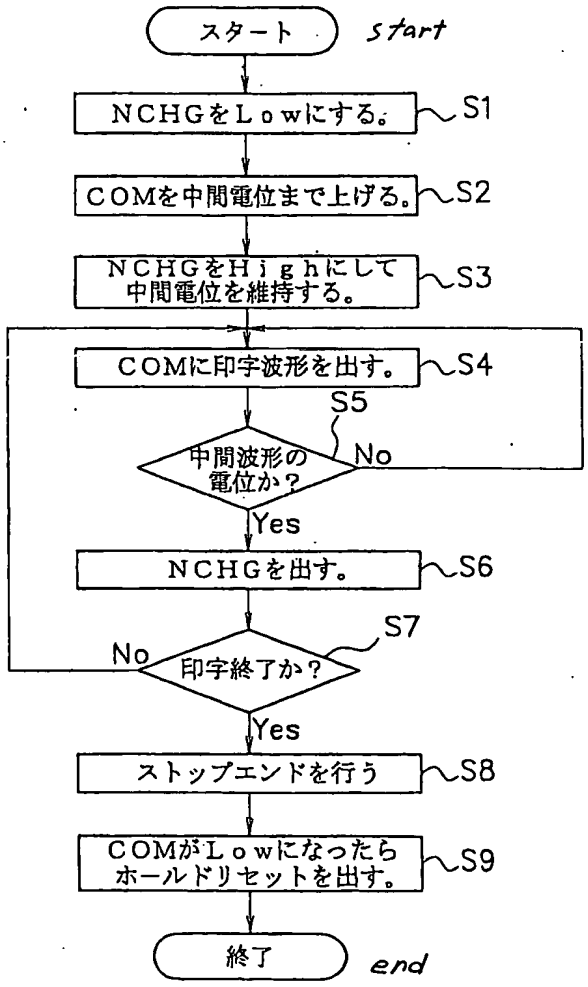


Fig. 5

Fig. 6



S1: turn NCHG to L level

S2: boost potential of COM up to Vc

S3: turn NCHG to H level

S4: output COM to voltage holder

S5: potential of COM is lower than Vc?

S6: turn NCHG to L level

S7: printing is finished?

S8: termination processing

S9: output reset signal when potential of COM becomes VL